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GROUND-WATER CONTAMINATION

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and/et

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Association canadienne des ressources hydriques

Abstracts

Session 1:

ORGANIC CONTAMINANTS

AQUIFER VULNERABILITY STUDY

by

F.B. Cruickshanks, J.E. Gibb and T.W. Hennigar[1]

Environment Canada, in co-operation with Agriculture Canada, is developing a pro-active or anticipatory programme to determine the environmental behaviour of pesticides and nitrates under Atlantic Canadian conditions. This approach is intended to provide interested parties with the needed protocols for evaluating the chemistry and fate of agricultural chemicals, particularly as they relate to the new guidelines for the registration of pesticides of Canada. Also, to determine under what agricultural practices particular pesticides and fertilizers can be applied without causing unacceptable contamination of ground waters. Certain pesticides suspected of being soluble and persistent enough to contaminate ground waters will be subjected to controlled field applications.

The Sheffield Farm Research Station, located 5 km north of Kentville in the Annapolis-Cornwallis Valley of Nova Scotia, was chosen as a suitable aquifer vulnerability study area. A large part of the farm is covered with well-drained sandy loams that are frequently used for potato, berry, tobacco and orchard crops; the aquifers beneath these permeable soils are vulnerable to contamination by pesticide and fertilizer residues.

During the 1988 field season, reconnaissance hydrogeological studies were carried out on Sheffield Farm. These included detailed coring of the soil materials and bedrock, split spoon sampling, installation of 19 5-cm diameter piezometers in the completed boreholes, a limited number of hydraulic tests and some ground- and surface-water sampling. Piezometer development, using air lift combined with ground water from the site, was approximately eighty percent completed.

Ongoing work plans include the development of a computerized data base, spatial analysis of the data, the completion of piezometer development and water sampling and analysis, hydraulic conductivity testing, surface-water hydrometrics including tile drain effluent from neighbouring farms, terrain and borehole geophysics, the updating of soils mapping, surficial and bedrock geology and land use. Much of this is being co-ordinated with the Centre for Water Resources Studies of the Technical University of Nova Scotia in Halifax and the National Hydrology Research Institute.

Field experiments will be conducted upon completion of activities related to instrumentation, sampling, data review and interpretation. Three suggested experiments include a follow-up to the Prince Edward Island aldicarb monitoring. A second experiment might concern the use of insecticides or fumigants that have been detected in British Columbia ground waters. A third experiment could involve the application of atrazine to corn crops.

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INVESTIGATION OF PESTICIDES IN GROUND WATER BENEATH AN IRRIGATED FIELD NEAR OUTLOOK, SASKATCHEWAN

by

D. McNaughton[1], R. Grover[2], W. Nicholaichuk[1], and G. Grove[1]

The Federal ground-water pesticides study programme was begun in 1986, and has been aimed at surveying ground-water supply aquifers beneath agricultural lands at various sites across the three westernmost provinces. One such site is the Pederson Site, near Outlook, Saskatchewan which has been investigated through the joint efforts of the National Hydrology Research Institute, Saskatoon, and Agriculture Canada, Regina.

The Pederson Site is irrigated during the growing season using the gravity corrugation method. Water levels were monitored in all on-site observation wells and water samples were extracted at various times dependant upon the irrigation schedule over the summer months of 1987 and 1988.

The observation well hydrographs indicate that infiltration of ground water through the aeolian sediments overlying the site is quite rapid, despite the fineness of these materials. Hydrochemical samples indicate a very high total dissolved solids and dissolved organic carbon concentration in the shallow ground waters, which could affect the transport of pesticide contaminants through the unsaturated zone.

Pesticide analytical results show that despite the irrigation of the site, the rapid infiltration of ground waters to the saturated zone, and the high natural organic carbon content of the ground waters, the observed pesticide content of the ground water is low.

The observed levels of pesticide in ground water beneath the Pederson Site would indicate that if this is typical of an irrigated prairie field, the amount of the parent pesticides reaching the ground-water table under these conditions is small. Further work on this subject is being planned. It is expected that in order to understand better the processes of retardation, sorption, and degradation acting on pesticides used in this sort of environment, some process of labelling and detection of both infiltrating water, and target compounds will be necessary. In future work of this nature, attention will be focussed on the unsaturated zone, for it is here that the physical, chemical, and biological processes of degradation occur which decide the impact of pesticide contamination on ground-water quality.

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LEACHING OF ATRAZINE AND ITS METABOLITES IN SOIL AND GROUND WATER

by

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A field study was undertaken in the summer of 1988 to investigate leaching characteristics of atrazine and its dealkylated metabolites in two agricultural soils of Quebec, namely St. Amable sand and St. Laurent clay. The field half-life of atrazine in both soils was found to be less than two weeks. Beyond the first 20 cm from the soil surface, atrazine levels were found to be higher in the clay soil than in the sandy soil. This was also confirmed by higher levels of atrazine in the ground water of the clay field. Deethylatrazine was the only metabolite found in any significant quantity in both soils. Again, levels were more important in the clay field. In the ground-water zone, however, only deisopropylatrazine was detected and levels were similar in both fields. The analysis of the metabolites seems to indicate that the transformation of atrazine into deisopropylatrazine occurs in saturated conditions while, in the unsaturated zone, deethylatrazine is the major degradation product. Combining atrazine results with its phytotoxic metabolite, deisopropylatrazine, has revealed that the Canadian drinking water standard for atrazine (2 ppb) was exceeded from August to the end of the sample period in October in the ground water of the clay field. In the sandy field, combined concentrations were 3.16 ppb by the end of October.

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THE SORPTION OF TRICHLOROETHYLENE IN CLAYEY TILL

by

L.D. McKay[1] and M.R. Trudell[2]

A laboratory study was conducted to evaluate the relative contribution of organic carbon and mineral matter to the sorption of trichloroethylene (TCE) in clay-rich till. Partition coefficients for TCE were determined from laboratory batch tests using ^{14}C labelled TCE. The natural organic carbon content of two till samples was 0.68% and 1.95%. Three samples were baked at 250 to 375°C for 8 to 24 hours, reducing the organic carbon content by 44 to 90%. Partition coefficients of the natural samples were 58.6 and 125, compared to the baked samples which ranged from 0.55 to 2.4.

Baking of the till samples appeared to have little effect on the mineral matter, but greatly reduced the sorptive capacity of the till. The results indicated that sorption of TCE is dominated by the naturally occurring organic carbon. Sorption by mineral matter in the till is negligible, relative to that by organic carbon. Sorption follows the carbon-referenced model of Karikhoff (1984). However, the

sorptive characteristics of the organic carbon in the till, as represented by laboratory-based partition coefficients of organic carbon (K_{oc}), are much greater than previously reported for a variety of organic carbon sources.

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FIELD APPLICATION OF THE VULPEST MODEL ON TWO LYSIMETER NETWORKS IN QUEBEC

par

R. Martel[1], O. Banton[2] et J.-P. Villeneuve[2]

Le modèle Vulpest développé à l'INRS-EAU prédit la quantité de pesticides qui peut parvenir à la nappe d'eau souterraine. Il est conçu pour être utilisé par des gestionnaires et s'avère un outil précieux d'aide à la décision pour ceux qui doivent régir l'utilisation des pesticides et pour ceux qui se préoccupent de la conservation de la qualité des eaux souterraines.

L'échantillonnage de l'eau interstitielle dans la zone non-saturée de deux champs expérimentaux du Québec (l'Assomption et Saint-Augustin), par un réseau de lysimètres, a généré à ce jour un grand nombre de données. Ces champs cultivés pour le maïs sucré et la luzerne ont subi des applications de différents pesticides (atrazine, simazine, diméthoate et carbofurane) aux doses usuelles des pratiques culturales entre 1986 et 1988. Les paramètres physiques du sol ont été mesurés à ces deux sites en vingt-cinq (25) points sur chacun des trois horizons de sol afin de déterminer les distributions statistiques de ces paramètres.

Les résultats obtenus par le modèle Vulpest ont été comparés aux analyses de pesticides dans l'eau du sol. La qualité des résultats qui prennent en compte la variabilité spatiale des paramètres régissant la migration des pesticides en zone non saturée est discutée pour chaque pesticide. Cette application qui a permis de vérifier au champs la validité du modèle Vulpest montre la qualité des résultats qui aurait pu être obtenue avant même l'application d'un de ces pesticides.

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COUPLING VULPEST WITH A (SATURATED ZONE) SOLUTE TRANSPORT MODEL TO DELINEATE WELLHEAD PROTECTION AREAS IN AGRICULTURAL ZONES

by

O. Banton, P. Lafrance and J.-P. Villeneuve[1]

A wellhead protection area (WHPA) is the surface and subsurface area surrounding a waterwell through which contaminants are reasonably likely to move toward and reach. In the past, various approaches have been taken to delineate a WHPA: fixed circles or rings around the well; simplified variable shapes based on hydrological mapping and classification; zones with prescribed minimum travel times. However, in establishing WHPA's, many factors need to be considered: the zone of influence around the well; interference from neighbouring wells; water-table drawdown by the well; well recharge area; sources of contamination; flow paths; transport velocities; travel times. To determine a site-specific WHPA, a systematic analytical approach must be taken. Mathematical simulation models may be employed and are often the only method capable of determining the WHPA when quantitative criteria are used.

This approach can be used in agricultural areas, where pesticides are applied, by coupling the VULPEST model with a (saturated zone) solute transport model. VULPEST evaluates the concentrations of pesticide that reach the water table, taking into account the spatial variability of soil physical parameters of the vadose zone. These concentrations are used as input data in a model which simulates the transport and the fate of the contaminant in the saturated zone. This model considers the flow velocities and the influence of each well. The quantitative results obtained by these means determine the WHPA for each specific contaminant, i.e. each pesticide. Depending on the aquifer structure or the flow pattern, a 2-or 3-dimensional model can be used. The case study provided in this paper shows an example of the possible and future applications of such a method.

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Session 2:

INORGANIC CONTAMINANTS

APPLICATION OF THE GROUND-WATER ATTENUATION ZONE CONCEPT TO LANDFILL SITE CLOSURE: A CASE STUDY

by

Craig Wardlaw[1]

Attenuation of contaminants in ground water is a process which has been used, knowingly or not, for many years in the design and closure of landfill sites. The setting of formal attenuation zones around landfill sites is a recent development and is a procedure which is not yet well defined. The attenuation zone concept was used in the closure of the landfill site at CFS Sioux Lookout, Sioux Lookout, Ontario. Water samples from the unsaturated zone around the site showed levels of inorganic substances well above Ontario drinking-water and surface-water standards. Attenuation zones were delineated, by the consultant to the Department of National Defence, to restrict the uses of the water in the area and to satisfy regulatory officials that surface water was not at risk. The process of defining the attenuation zone was very unstructured and raised a number of questions regarding the application of the concept. Many of those question were answered by reviewing the literature, design manuals and government guidelines. Attenuation appears to be a poorly understood process from the mathematical and operative point-of-view but there is a large body of knowledge based on observed effects and empirical modelling. There is a distinct lack of formal design protocols for delineating attenuation zones. The drafting of such protocols would help unify procedures used by different design groups and regulatory officials and would ease some of the fears of the public and site owners.

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MONITORING AND CONTROL OF SUBSURFACE MIGRATION OF SALINE FLUIDS IN THE VICINITY OF A POTASH WASTE DISPOSAL BASIN NEAR VANSCOY, SASKATCHEWAN

by

H. Maathuis[1]

A detailed case history is presented of the impact of a potash mine waste-disposal facility on the local hydrogeological environment and the possible means to control subsurface migration of saline fluids originating from the disposal site. The surface waste-disposal facilities are an integral part of the local hydrogeological environment which, in ascending order, consists of a basal aquitard, a shallow intertill aquifer and an upper aquitard. Within the area of the waste-disposal basin vertical migration of brine occurs beneath the brine pond and beneath an old decanting area. The average rate of downward movement is estimated to be in the order of three centimetres per year. Low hydraulic conductivity of the upper aquitard and the loading effect of the salt tailings pile has resulted in increased pore pressures in the aquitard beneath the pile. The increased pore pressures act as a barrier to downward migration of brine and protect the shallow intertill aquifer, as long as loading continues. There is no evidence of

contamination of the aquifer. If it occurs at some point in time, it can effectively be controlled by means of hydrodynamic containment. Shallow lateral migration of saline fluids occurs within the saturated zone of the oxidized zone of the upper aquitard. The present rate of lateral migration is in the order of several metres per year but will decrease as the front moves away from the waste-disposal site. Hydraulic head or hydraulic conductivity control can halt shallow lateral migration.

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CONCEPTS FOR HAZARDOUS WASTE DISPOSAL IN SOUTHERN SASKATCHEWAN BY BURIAL IN GLACIAL TILL

by

J.A. Cherry[1], G. van der Kamp[2] and C.K. Keller[3]

Facilities for the disposal of hazardous waste should be sited and designed so as to minimize subsurface movement of contaminants. The hydrogeology of southern Saskatchewan appears to be very well suited to this criterion. For most of the area the near-surface geological setting consists of 50 to 150 metres of glacial drift - mostly clayey till, underlain by hundreds of metres of Cretaceous shales. At many locations, no useful aquifers are present either in the drift, or in the shales. Some of these locations would constitute excellent hydrogeological settings for hazardous-waste disposal by burial within the glacial till.

Both site-specific and regional studies have shown that thick till units with a bulk permeability of less than 10^{-10} m/sec are widely distributed. Hydraulic, chemical and isotope data show that the rate of ground-water movement in such tills is less than one centimetre per year. At any particular site, the low permeability of such a till unit can be confirmed by well-documented and inexpensive tests. The hydrogeological properties of the shales are less well-known, but it is clear that the shales generally have low permeability and can be considered as a hydrological inactive base below the drift. Due to their low permeability and homogeneity, the glacial tills would provide the prime hydrogeological barrier to contaminant movement.

With respect to hydrogeological criteria, the most favourable sites would probably have a thick glacial drift consisting entirely of till, underlain by shale, with no aquifers anywhere nearby, and with a downward hydraulic gradient. Design of a facility for hazardous-waste disposal in such a setting would take advantage of the properties of the clayey till to minimize contaminant migration. Flow away from wastes buried deep in the till would not exceed one centimetre per year, so that contaminant migration would be essentially by diffusion, further reduced by adsorption on the clay fraction. Such a facility would provide reliable containment for thousands of years.

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A GROUND-WATER CONTAMINANT TRANSPORT MODEL VALIDATION STUDY AT THE CHALK RIVER NUCLEAR LABORATORIES

by

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Regulations for on-land waste management facilities frequently call for hydrogeological modelling of potential subsurface contaminant transport as part of the site approval application. Regulators are, however, generally uncertain of the reliability of such modelling submissions, both as a function of the database and of the models employed. The U.S. Nuclear Regulatory Commission contracted Battelle Pacific Northwest Laboratory (PNL) and Chalk River Nuclear Laboratories (CRNL) to apply a state-of-the-art contaminant transport code to well-characterized, contaminated, porous media flow systems in a study to address the concerns outlined above. PNL's finite element CFEST (Coupled Fluid, Energy, and Solute Transport) code was applied to CRNL's Nitrate Plant radiostrontium plume as one stage in this study.

The Nitrate Plant Plume originates from accidental releases of fission product-contaminated solutions to an infiltration pit in 1953/54. The pit overlies an unconfined flow system in aeolian and fluvial sands, with ground-water flow velocities averaging 30 cm d^{-1}. Geology and hydrogeology of the aquifer have been defined in detail, and confidence in the conceptual model derived from the information has been bolstered by previous, successful, numerical simulations of the flow system. The movement and spatial distribution of the radiostrontium plume have been determined repeatedly over the past 35 years, and these data are augmented with abundant information on the sorption behaviour of ^{90}Sr from conventional laboratory testing procedures, from longer term column experiments, and from the Nitrate Plant Plume itself.

The CFEST code employs a 2- or 3-dimensional finite-element solution to the standard advection-dispersion equation, with capabilities for simulating the transport of heat and of radioactive or stable contaminants. Like all multidimensional simulation codes, interactions between contaminants and the aquifer matrix are modelled as instantaneous, reversible reactions. The package features pre- and post-processing routines to simplify use and data presentation; its solution approach and capabilities are representative of the majority of large-scale codes currently in use for predicting subsurface contaminant movement.

Simulations of ground-water movement at the Nitrate Plant site were very successful in producing close matches between observed and computed head distributions, both when a limited and when the complete hydrogeological data set were used as model input. This similarity is attributed to the geological simplicity of the Nitrate Plant site flow system, and should not be considered to be a universal phenomenon. Simulations of hydrogeologically complex sites are likely to show substantial output differences with different amounts of input data.

Results of the simulation of ^{90}Sr distribution were, after sufficient model adjustment, fairly close to that actually observed. This study, however, provided the luxuries of hindsight and of long-term site specific data in making the model adjustments. For successful, truly predictive, simulations the results of this study indicate that an improved understanding and modelling of contaminant sorption geochemistry remains a high priority.

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NITRATE CONTAMINATION OF THE ABBOTSFORD AQUIFER, BRITISH COLUMBIA

by

A.P. Kohut, S. Sather, J. Kwong and F. Chwojka[1]

In southwestern British Columbia, a significant portion of the glacial fluvial sand and gravel deposits comprising the Abbotsford Aquifer is contaminated by nitrates exceeding the provincial drinking water quality standard of 10 mg/L as nitrate-nitrogen (NO_3-N). This essentially unconfined aquifer is up to 60 m in thickness and occupies a semi-circular upland area of 50 km² adjacent to the Canada - U.S.A. border. Ground-water flow emanates radially from the central portion of the upland (recharge area) towards its outlying boundaries where discharge is evident along the peripheral toe of the upland. Non-pumping water levels range from near ground surface to 40 m below ground. Water-quality data obtained from long-term monitoring of a number of sites over a 15-year period indicate that nitrate concentrations vary seasonally. Highest nitrate concentrations generally occur during the winter months when nitrate is leached to the water table during recharge from infiltrating precipitation and rising water-table conditions. An increasing temporal trend in nitrate concentration is generally evident in ground waters within the eastern discharge area where nitrate-nitrogen levels have risen at one site from 1.2 mg/L in 1974 to 8.3 mg/L in 1984. Site specific determinations of water quality with depth at a control site instrumented with 12 standpipe piezometers indicate that nitrate concentrations decrease with depth. Ground water high in nitrates correlates significantly with increased concentrations of chloride and specific conductance suggesting an organic source of contaminants such as animal wastes. Absence of tritium in ground water from domestic wells as shallow as 10 m in depth suggests a relatively long history of nitrate contamination probably originating after World War II. $\delta^{15}N$ isotope determinations indicate enrichment of ^{15}N with values of $\delta^{15}N$ in the range +5.5 to +23.7 ppt. indicative of nitrogen derived from organic sources such as soil humus and animal wastes. These results, and observations of land-use practices, indicate that poultry manure wastes which are inappropriately stored, disposed of and applied to the land are a principle source of nitrate contamination of ground waters in the area.

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Session 3:

SAMPLING AND ANALYSIS PROTOCOLS

SAMPLING AND ANALYSIS OF GROUND-WATER QUALITY AT HAZARDOUS WASTE SITES IN EASTERN CANADA

by

R.E. Jackson, S. Lesage and M.W. Priddle[1]

Ground-water quality data from five hazardous-waste sites in eastern Canada are reviewed and the contaminants of concern are identified. At three of the sites, contamination is due to the presence of dense, non-aqueous phase liquids (DNAPLs); DNAPLs are suspected at the other two. These have partially dissolved to create plumes of chemicals comprising the contaminants of concern, e.g., halogenated aliphatics, various aromatics and PCBs. Methods of field sampling, preservation and analysis for such polluted ground waters are described. The use of a coupled gas chromatograph-mass spectrometer (GC-MS) for quantitative organic analysis of ground-water pollutants is presented and the particular problem of the analysis of heavily-polluted samples is discussed. The principal elements of NWRI's quality assurance/quality control programme for heavily polluted ground waters is explained, with an emphasis on obtaining data of high precision and accuracy in spite of matrices of great complexity.

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TRACE CHEMICAL ANALYSIS: MINIMIZING ERRORS IN A SURVEY OF WELLS FOR SELECTED HERBICIDES

by

S.A. Schuette, R.G. Smith, L.R. Holden and J.A. Graham[1]

Analyses of well water samples should be performed so as to minimize the frequency of so called "false negatives" and "false positives". Lack of understanding of capabilities and limitations of an analytical method may cause interpretation errors which may lead, at the least, to misunderstandings and possibly regulatory action or even litigation. As part of Monsanto's National Alachlor Well Water Survey, samples from over 1,600 U.S. wells were analyzed for five popular corn and soybean herbicides, alachlor, atrazine, cyanazine, metolachlor, and simazine. A description of the Analytical Protocol utilized in the study follows.

Following collection and refrigerated shipment to the laboratory, duplicate 0.5 litre samples from each well are spiked with the deuterium-labelled analogs of each herbicide. The analytes are then enriched octadecylsilica solid phase extraction columns, eluted, and the volume of the extract adjusted to approximately 1.0 mL. Quantitation of the analytes in the extract is accomplished with capillary Gas Chromatography-Mass Spectrometry (GC-MS). The GC-MS procedure relies on electron ionization and subsequent selected ion monitoring of two ions for each analyte. For each analyte, levels in the sample are determined based on the ratio of the area of the peak of the corresponding stable labelled internal standard to the area of the peak of the analyte of interest. Included in each sample set, which consists of duplicate extracts from 8-16 wells, are duplicate response curve standards at eight levels from

0.0 to 2.0 µg/L of each analyte, duplicate quality-control (QC) samples, deionized water blanks and duplicate deionized water fortified with each of the analytes. The injection sequence is arranged so that all duplicates are separated by one-half of the job so as to minimize the problems caused by brief lapses in instru-ment performance such as a plugged autosampler needle. Standards are also arranged in an alternating pattern (i.e. neither ascending nor descending order) which minimizes the effect of gradual changes in instrument performance (such as decreasing detector response caused by a dirty source) on the quantitative results. Most unique about the method is the way analytical results are plotted and the way these plots and the data are used to evaluate samples on an individual basis. A single predetermined detection limit, which may or may not be realistic on a given day, is not part of the protocol. Instead, data for each analyte in a specific well are evaluated in the context of the data for all wells and QC samples obtained from that job. Samples for which all data points of a given analyte are clearly distinguishable from and greater than this "baseline concentration" are considered positive for that analyte. Data found near the "baseline concentration" are classified using the judgement of the analyst who, after viewing the data, the relative retention times, and the single ion chromato-grams, decides whether there is a high probability for the presence of the analyte in the well water.

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SOME EFFECTS OF COLD WEATHER ON THE OPERATION OF A GROUND-WATER MONITORING NETWORK

by

J. Olson and D.A. Hackbarth[1]

Long-term ground-water monitoring at the Alberta Special Waste Treatment Centre near Swan Hills, Alberta, has produced some observations that are not normally considered during the design of a monitoring project or the development of sampling protocols for a site investigation.

Climate can regulate the length of the active monitoring season for the shallow ground-water monitors at the site. Monitor freeze-up can occur at any time between October and December and the subsequent thaw may not occur until the following June. This can create a five-to-six month sampling window for the shallow monitors. Preliminary evidence indicates that frost action may be ejecting the monitors from the ground. Top of casing elevations have increased by as much as 0.23 m since the monitoring network was installed in May, 1985. Monitor completion into unsaturated portions of a borehole may be responsible for increased sulphate concentrations in the ground water. Changes in ground-water sampling methologies introduce deviations in the analytical data. The length of the completion interval is important when installing ground-water quality monitors in a low permeability medium.

Conclusions reached during the monitoring included: only warm-weather sampling of some monitors is possible; the potential effects of frost action should be considered; sampling protocols should be well thought out before their implementation and any deviations from the methods chosen should be well documented; everything possible should be learned about the completion interval during the installation of a monitor.

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AN EXPERT SYSTEM FOR SITING DRILLING WASTE SUMPS

by

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and T.M. Macyk[2]

Leachate generated at the sites of drilling waste sumps frequently contains large concentrations of inorganic and organic constituents. The migration of the leachate in the subsurface and its emergence at the ground surface can cause serious environmental damage by contaminating aquifers and by polluting the biosphere. Consequently, the site where a sump is to be constructed must be chosen carefully to minimize the spread of the leachate. This selection requires expertise in contaminant hydrogeology and other disciplines. Most industry and regulatory personnel now selecting sites in Alberta do not have this expertise.

This paper presents the results of a study which assessed the feasibility of building an expert system to assist industry and regulatory personnel with the selection of suitable sites. Expert systems are computer programs that assist users in solving difficult problems quickly and effectively. These systems can do this because they have the specific knowledge used by experts to solve a particular problem. Therefore, nonexpert users should arrive at the same answer as an expert for the same problem.

A demonstration prototype of a proposed expert system that assists in selecting sump sites was designed in this study. The main components of the system are a user/system interface and a set of contaminant transport models. Users provide data at the beginning of a session that are specific to a proposed sump site. Full support and assistance is provided by the system if requested by the user. This is in the form of factual and heuristic (rule-of-thumb) information. Once a complete set of data are entered, the system selects an appropriate contaminant transport model which processes the data. The system then evaluates the model's results and provides the user with (a) information on the acceptability of the site, (b) reasons for rejecting a site if the system determined that it was not acceptable, and (c) a statement on the system's degree of confidence in its assessment. Although not part of the present prototype, an additional component to the system could be added that would provide recommendations for making an unsuitable site acceptable.

The results of the study have shown that it is feasible to build the proposed expert system. A large portion of the information (i.e., expertise) needed for the system can be adapted from an existing expert system. The remaining information can be acquired from the literature, from industry and regulatory sources, and from the results of field investigations of existing sumps. The study also illustrates that an expert systems approach may be superior to most traditional methodologies for selecting sites for the disposal of many types of waste.

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Session 4:

WATER/AQUIFER INTERACTIONS

GROUND-WATER FLOW AND CHEMISTRY IN A SMALL ACID-STRESSED SUB-CATCHMENT IN THE CANADIAN SHIELD

by

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The purpose of this study is to identify flow pathways of acidic precipitation in the terrestrial portion of a Canadian Shield catchment and with this knowledge determine the geochemical reactions between the precipitation and the soil-till matrix. A good understanding of the subsurface flow network and the interaction of the percola-ting waters with the tills is needed to predict long-term impacts of acid precipita-tion on ground-water quality. As streamflow largely results from short- to long-resi-dence time ground water, it follows that understanding the acidification of terres-trial systems will significantly aid our ability to predict long-term trends in sur-face-water acidification.

Studies examining ground-water contribution to streamflow have taken two general approaches. The first is a 'black box' treatment where stable isotope ratios in stream water are compared to phreatic zone and precipitation values. Results indicate a very significant fraction of the stream volume during precipitation events is longer residence time ground water. A second approach involves instrumenting the catchment with monitoring wells to determine the ground-water response to a precipitation event. In homogeneous regimes, the capillary fringe effect has been identified as a major hydrological process responsible for contributing significant quantities of longer residence time water to streams during precipitation events (Abdul and Gillham, 1984). Application of this result to Canadian Shield catchments, which have very complex, heterogeneous till deposits, is questionable.

This study examines the input of ground water to a Canadian Shield stream using hydrological and chemical data measured directly from the ground-water system. The study area is located 12 km southeast of Huntsville, Ontario in the Harp Lake drainage basin. This study is focused on a small sub-catchment called Harp 4-21. Sustained streamflow during the dry summer months indicates that ground water contributes a significant amount of water to the hydrological budget of the sub-catchment. The installation of a ground-water monitoring network in 1988, consisting of 70 wells (piezometer nests and water-table wells), allowed the collection of hydrological and chemical data. The extremely heterogeneous nature of the geological deposits, and the added constraint that the drilling process cause minimal disturbance to the basin, made the well installations very difficult.

Hydraulic head data, collected from these wells on an ongoing basis, has allowed the determination of the general ground-water flow pattern. To aid in the construc-tion of the flow field, conventional slug tests, permeameter and grain-size analysis were performed and a detailed refraction seismic geophysical survey conducted to obtain a three-dimensional picture of the basin.

Samples for complete cation and anion analysis have been extracted solely from stainless steel tipped piezometers. Alkalinity generation and geochemical evolution of ground waters is controlled by feldspar weathering and not carbonate dissolution (as commonly observed in southcentral Ontario).

The information collected during this study can now be input into geochemical and hydrogeological models with the confidence that the field conditions are well represented. With the current trend towards using models as a descriptive and predictive tool such field-based input data are imperative, since model output can only be as good as the input.

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SEASONAL VARIATION IN GROUND-WATER FLOW AND ITS INFLUENCE ON SALINITY PATTERNS AROUND A PRAIRIE SLOUGH

by

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Soil salinity is becoming increasingly detrimental to the agricultural potential of many prairie lands. Much of this is due to regional ground-water flow patterns, but more and more is associated with the drainage of wetlands. This type of soil salinization does not appear to be associated with regional ground water and the mechanism of salinization is not fully understood at present.

This paper reports on a finite-element simulation of both the flow patterns and salt migration around a slough in western Manitoba which had been fairly thoroughly instrumented and investigated. Although the data available on which to base the modelling was relatively crude, it was found that patterns of salinity concentrations predicted by the models closely corresponded to those measured in the field, leading to the conclusion that the simulated flow patterns accurately portray those actually occurring.

The modelling indicated that the till underlying the slough, and the head in the aquifer under the till, prevented any significant interchange of water between the slough and the aquifer. Instead, the slough drained upslope through the unsaturated, more permeable surface layer to those zones where evapotranspiration was occurring. It was found that the strong fluxes out of the slough moved the salts originally in that region upslope. The major concentrations of salt occurred in midslope because below that the fluxes were still moving the salts outward, and above that, it appeared that the permeability of the unsaturated surface layer was not sufficient to allow significant upslope flow. Further study is still required on the influence of the flushing action of fall rainfall, salt migration during the winter, and rooting depth on the salinity patterns.

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ENVIRONMENTAL ISOTOPE AND GEOCHEMICAL STUDY OF LANDFILL LEACHATE MIGRATION

by

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The Essex County Sanitary Landfill Site No. 2 is located in southwestern Ontario about 40 km southeast of the City of Windsor. The landfilling consists of a regulated disposal of municipal wastes into an abandoned sand and gravel pit. Landfill refuse cells are situated on a surficial ground-water recharge zone composed of medium to fine sand. The water-table aquifer is perched and ground-water flow is predominantly towards the east and southeast.

Previous studies have suggested that a leachate plume is migrating down gradient from the landfill within the water-table aquifer. This paper discusses the use of the

environmental isotopes, oxygen-18 and deuterium, as diagnostic parameters to assess the effects of dilution as an attenuating process in the ground-water setting and to define the extent of the leachate plume. The measurement of major ions in the leachate and ground water is used to develop the conclusions.

A comparison of oxygen-18 and deuterium concentrations in the landfill leachate to oxygen-18 and deuterium concentrations in the precipitation of southwestern Ontario and in background ground-water samples, suggests that oxygen-18 concentrations in the leachate are enriched by 0.5 to 1.0‰ and that deuterium concentrations in the leachate are enriched by 10 to 20‰. Analysis of subsurface chemical reactions suggests that the isotopic enrichment is the result of organic decomposition within the landfill leachate. The oxygen-18 enrichment may be the product of the oxygen-18 in carbon dioxide, enriched relative to the decomposing plume organics, equilibrating with the oxygen-18 in the leachate. Hydrogen fractionation during hydrogen sulphide production is apparently the cause of the deuterium enrichment in the leachate.

Beyond the landfill refuse, the isotopically enriched oxygen-18 and deuterium concentrations in the leachate behave as conservative tracers with dilution as the attenuating process. Collation of oxygen-18 and deuterium data with electrical conductivity and the inorganic parameters: chloride, sodium, potassium and bicarbonate; shows strong linear relationships suggesting that these parameters are attenuated predominantly by dilution. Inverse and poorer linear relationships of oxygen-18 and deuterium with calcium and sulphate suggest the occurrence of other attenuating processes such as cation exchange or bacterial reduction, respectively. Further analysis of oxygen-18, deuterium, chloride, sodium, potassium and bicarbonate data suggests that leachate migrates laterally beyond the boundaries of the monitoring network and vertically towards a deeper, partly confined, sand aquifer.

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POTENTIAL GROUND-WATER QUALITY DEGRADATION FROM IRRIGATION OVER A SHALLOW SANDSTONE AQUIFER IN SOUTHERN ALBERTA

by

C. Robertson[1]

Irrigation has been proposed for a portion of the land overlying the Milk River aquifer in southern Alberta, Canada. A study was conducted to determine the potential effect of the proposed irrigation on water quality within a shallow, unconfined section of the aquifer. Methods used included geological test drilling, the installation and monitoring of piezometers and water-table wells, chemical and isotopic analysis of ground water and ground-water flow modelling.

Water quality changes from >5000 mg/L total dissolved solids to <1000 mg/L along the flow path. The aquifer is dominated by Ca^{2+}, Mg^{2+}, and SO_4^{2-} in the recharge zone and Na^+ and HCO_3^- where ground water discharges into the Milk River. Stable isotopes of oxygen-18 and deuterium are enriched along the flow path.

The travel times of ground-water flow within the aquifer is >28 000 years. It is postulated that good quality ground water at the discharge end was recharged prior to the last glacial advance. The poor quality ground water is post-glacial in age and recharged through glacial till.

The introduction of irrigation to the area will potentially result in recharge to the aquifer through the glacial till. Subsequent subsurface irrigation return flow could increase total dissolved solids and the ground water could become unfit for domestic use.

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SURFACE AREA AND SORPTION

by

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The importance of hydraulic conductivity heterogeneities in controlling the dispersion of contaminants in ground-water flow systems is now well recognized. Given the very wide ranges in sorption properties of geological materials for many contaminants, it seems probable that the transport and spreading of many subsurface pollutants may be even more strongly influenced by heterogeneities in the aquifer's capacity for and rate of solid/solution reactions. Although the ultimate objective of the program reported here is to investigate such heterogeneities and their influence on ground-water contaminant transport, the first task has been to determine and demonstrate a reliable method for measuring the sorption capacity of geological materials.

Previous work at CRNL has shown that gas adsorption (BET) surface area is a much better predictor of long-term sorption capacity for a number of radionuclides than other physical properties of sediments. Surface area measurements include the effects of grain size, mineralogic, and weathering variations in aquifer sediments. Most of the earlier testing evaluated subsamples of materials with identical contaminant exposure history. Data reported here extends the evaluation of surface area to 32 sediments collected from various stratigraphic units and locations in a single, well-defined plume of ^{90}Sr contamination. Good correlation was observed between surface area measurements and "*in situ* K_d" measurements - distribution ratios determined from contaminated aquifer sediments and their associated pore waters.

At the study site, several stratigraphic units have been defined on the basis of grain-size (and hydraulic-conductivity) variations. Thus, within these units (which range from silts to medium sands), most of the surface area variability resulting from grain-size variations is removed. Despite the elimination of grain size as a variable, *in situ* K_ds within the individual stratigraphic units continue to show large ranges of values. The *in situ* K_ds do, however, remain moderately correlated with the variations in surface area measurements, illustrating the importance of local variations in mineralogy and (less quantifiably but probably more significantly) in the development of alteration coatings and precipitates on the grain surfaces. Current studies are extending the evaluation of surface area and long-term sorption relationships to other contaminants in other aquifers. Plans for examining the spatial structure of heterogeneities, using materials from an aquifer already characterized in detail for hydraulic conductivity variability, will be presented.

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